EMERGENCE OF MAYFLIES (EPHEMEROPTERA) FROM A NORTHERN BROWN-WATER STREAM OF ALBERTA, CANADA

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Verh. Internat. Verein. Limnol.	19	3022—3028	Stuttgart, Dezember 1975

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With 1 figure and 4 tables in the text

Introduction

The Bigoray River, a brown-water stream located in central Alberta, Canada, has been under investigation for a number of years. Eventually the stream is to be experimentally manipulated to assess the effect of pollutants on this type stream. Various

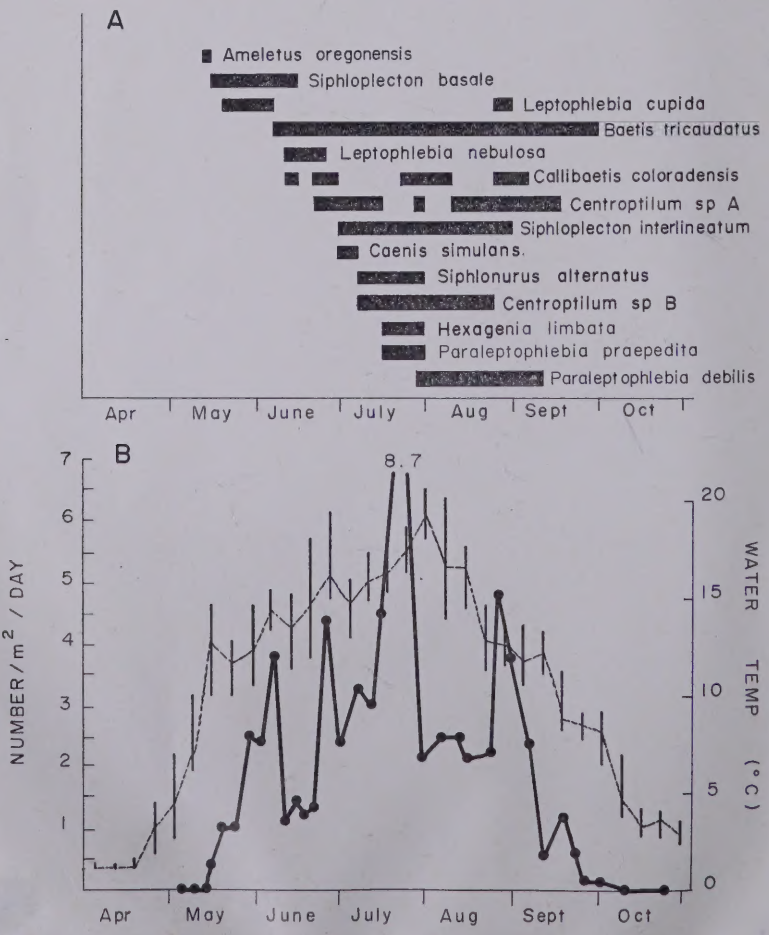

Fig. 1. A: Extent of emergence periods for individual species. B: Total numbers emerging per m^2 per day (heavy line) and mean weekly water temperatures (broken line). Vertical lines of water temperature graph indicate weekly maximum and minimum water temperatures.

aspects of the stream have been described by CLIFFORD (1969, 1972), CLIFFORD, ROBERTSON & ZELT (1973) and HAYDEN & CLIFFORD (1974). The 1969 report in part dealt with the seasonal changes in nymphal size-frequency distributions of the abundant mayfly (Ephemeroptera) species. Although these data provided information on the life cycles of the species, the species emergence period could only be approximated. This report describes a quantitative study of seasonal and diurnal periodicity of mayfly emergence from the northern brown-water stream. The study encompassed the entire emergence period.

Methods

Emerging mayflies were collected in floating box traps similar to those described by MORGAN & WADDELL (1961). Each trap covered a surface area of 0.1 m^2. In 1973, 16 traps were arranged in four transects along a 120-m stretch of the stream. The four traps of each transect were spaced across the width of the stream with the outer traps close to the shoreline. The distance between transects varied from 25 to 35 meters. The traps were operated continuously from 25 April to 23 October 1973 and were checked at 3- to 8-day intervals. Mayflies that died between sampling intervals were prevented from falling back into the water by wide, upward-sloping flanges within the traps. Experiments in which traps were emptied at 1-, 2- and 4-day intervals showed that there was no loss of specimens after 4 days. At 1- to 2-week intervals four additional traps were checked at hourly intervals for 24 hours.

Seasonal phenology

Of 15 species of mayflies collected during the study, 14 species emerged from the main stream (Fig. 1 A). One other species (*Siphlonurus phyllis* MCD.) was restricted to nearby borrow pits. In 1973 the mayflies of the main stream started to emerge on 15 May, at which time the mean daily water temp. was 10 °C. Mayflies continued to emerge until 1 October, the mean daily water temperature at this time having decreased to 8 °C (Fig. 1 B). Hence the total emergence period in this northern stream was 21 weeks. This encompassed about three quarters of the entire ice-free season. Emergence periods of individual species varied from 1 to 17 weeks, the average being 6 weeks. Except for the two species of *Centroptilum*, congeneric species showed little overlap in their emergence time. *Ameletus oregonensis*, *Siphloplecton basale*, and *Leptophlebia cupida* can be classified as early seasonal and *Paraleptophlebia debilis* as late seasonal, with the remaining species emerging in between the appearance of these two groups. The most intense period of emergence occurred during July, with 10 of the 14 species being on the wing at this time. HARPER & MAGNIN (1971), studying the emergence of mayflies from a stream in Quebec, Canada, noted two types of emergence patterns: a short and synchronized type and a gradual and dispersed type. In the Bigoray River study, *B. tricaudatus*, *Siphloplecton interlineatum* and *Centroptilum* sp. B would fit the dispersed type; the other mayflies exhibit the synchronized pattern (Tab. 1). *Leptophlebia cupida* and *L. nebulosa* can make up a large part of the nymphal population in the brown-water stream; but these two species accounted for only 8 % of the adult mayflies emerging from the main stream, because most of the nymphs move into tributaries and marshy areas prior to emergence (Tab. 2).

In the Bigoray River, *Siphlonurus alternatus*, *P. debilis*, and *Centroptilum* sp. B are known to be summer species, with growth, emergence, and reproduction taking place during a relatively short time in summer, the remainder of the year being spent in the egg stage. *S. alternatus*, emerging only during the last three weeks of July, accounted for the large number of mayflies emerging in mid-July; 6.2 adult *S. alternatus* per m^2 per day emerged between 15 July and 21 July. *P. debilis* is the last mayfly species to start emerging from the

Tab. 1. Mean number of mayflies of each species emerging per m^2 per day during each sampling interval and cumulative percentage emergence for all species during the emergence season. Ao, *A. oregonensis*; Sb, *S. basale*; Lc, *L. cupida*; Ln, *L. nebulosa*; Bt, *B. tricaudatus*; Cc, *C. coloradensis*; CA, *Centroptilum* sp. A; CB, *Centroptilum* sp. B; Si, *S. interlineatum*; Cs, *C. simulans*; Sa, *S. alternatus*; Hl, *H. limbata*; Pp, *P. praepedita*; Pd, *P. debilis*.

	Ao	Sb	Lc	Ln	Bt	Cc	CA	CB	Si	Cs	Sa	Hl	Pd	Pp	Cumul. % Emergence
May															
15	0.4														1
18		1.0													2
21		0.8	0.2												3
28		1.4	1.1												6
June															
4		2.0	0.4												9
7		3.6	0.2												14
11		0.9			0.2										16
14		0.4		0.8	0.2	0.2									18
18				0.3	0.9										20
21					1.3										22
25				0.2	2.4	0.2	1.8								28
July															
1					0.9	0.2	1.3								31
6					2.7		0.4		0.1	0.1					36
11					1.6		0.4	0.3			0.7				40
15					1.1		0.3		0.2		2.9				46
21					1.0			0.2	0.5		6.2	0.7	0.1		58
26					0.4	0.5		0.4	0.7		2.7	0.1	0.3		65
31					0.2	0.1	0.1	0.1	0.4		0.5	0.1	0.5	0.1	68
Aug.															
5					0.2	0.4		0.2	1.4					0.4	72
10					0.3	0.3		0.6	0.3					1.1	76
14							0.8	0.1	0.4					0.8	79
22					0.2		0.2	0.2	0.1					1.5	82
25			2.7		0.3	0.3			0.3					1.2	89
30			1.4		0.4	0.3	0.2		0.2					1.3	94
Sept.															
3					0.5	0.2	0.3							1.4	97
10					0.1		0.2							0.3	98
17					0.6		0.6								99
24					0.1										99
Oct.															
1					0.1										100

brown-water stream and the only species whose emergence period takes place almost entirely after July. In 1973, *P. debilis* started emerging at about the time that water temperatures were highest. *P. debilis* is not a summer species in warmer climates, e.g. southern Ontario (Sprules 1947), Oregon (Kraft 1964; Lehmkuhl & Anderson 1971).

Baetis tricaudatus, the most abundant species emerging from the main stream, had the longest emergence period, extending over 4 months with a few

Tab. 2. Number of specimens collected and the calculated yearly emergence for each mayfly species emerging from the stream.

	Total no. specimens collected	Number emerging per m^2 per year		
		Males	Females	Totals
Baetis tricaudatus Dodds	108	22.7	50.7	73.4
Siphlonurus alternatus (Say)	92	33.0	35.3	68.3
Siphloplecton basale (Walker)	52	18.6	25.9	44.5
Paraleptophlebia debilis (Walker)	44	10.6	30.7	41.3
Centroptilum sp. A	47	18.0	15.5	33.5
Leptophlebia cupida (Say)	20	9.2	14.9	24.1
Siphloplecton interlineatum (Walsh)	30	9.2	13.2	22.4
Callibaetis coloradensis Banks	14	9.9	2.5	12.4
Centroptilum sp. B	15	7.9	3.5	11.4
Hexagenia limbata (Serville)	7	2.4	2.8	5.2
Paraleptophlebia praepedita (Eaton)	7	2.6	2.0	4.6
Leptophlebia nebulosa (Walker)	7	3.0	1.4	4.4
Ameletus oregonensis McD.	2	0.8	0.8	1.6
Caenis simulans McD.	1	0.5	0.0	0.5
Totals	446	148.4	199.2	347.6

specimens on the wing even in early October. The life cycle of *B. tricaudatus* was difficult to interpret from nymphal growth data (Clifford 1969; Clifford, Robertson & Zelt 1973) and the emergence record does not add much in determining whether the species has a univoltine or bivoltine cycle. Unlike most of the other species, *B. tricaudatus* does not exhibit a major emergence peak; instead it emerges in what Macan (1958) calls "driblets" throughout the summer. The emergence data of *Centroptilum* sp. A possibly indicate a bivoltine cycle.

Diurnal periodicity of emergence

Emergence was essentially an afternoon and evening event, with 91 % of the mayflies emerging between 15.00 and 22.00 hours (Tab. 3). During the 24-hour emergence trials, which were carried out on 12 occasions during the summer, no emergence was observed from midnight to 09.00 hours. The mayflies that emerged between 18.00 and midnight were collected between 9—16 July, when some daylight was present almost until midnight. For example, on 16 July 1973 the light intensity in foot-candles was 5,500 at 18.00 hrs, 2,600 at 19.00 hrs, 810 at 20.00 hrs, 550 at 21.00 hrs, 410 at 22.00 hrs, 4 at 23.00 hrs and at midnight. In short, even *Hexagenia limbata*, which emerged latest in the evening, emerged while there still was some light.

There was no difference in the daily mean time of emergence of male and female *Baetis tricaudatus*, the only species collected in number sufficient to make such a comparison.

Emergence rates

Although emergence continued until 1 October, 90 % of the mayflies had emerged by the end of August, and 40 % emerged during July (Tab. 1, Fig. 1 B). On a rate basis, the combined emergence of *B. tricaudatus*, *S. alternatus*, *S. basale* and *P. debilis* accounted for 66 % of the mayflies emerging per m^2 per year (Tab. 2). Total emergence

Tab. 3. The percentages of mayflies emerging at different times during the day. There was no emergence from 24.00 to 09.00 hours. Numbers in parentheses after each species is the number of specimens collected.

	Mountain				Standard					Time				
	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
B. tricaudatus (77)	1	1		1	3	13	7	14	16	10	12	21	1	
S. basale (1)					100									
Centroptilum sp. A (5)						20	40	20	20					
S. alternatus (1)								100						
L. cupida (2)								50	50					
Centroptilum sp. B (2)										50		50		
C. simulans (6)											17	83		
H. limbata (2)														100
Total percentage	1	1	0	1	3	12	7	15	15	9	10	23	1	2

was 348 mayflies per m^2 per year. This rate is somewhat lower than mayfly emergence rates reported in other studies; e.g. 434 mayflies/m^2/yr for an Ontario (Canada) marsh (JUDD 1953), 628 mayflies/m^2/yr for an Oregon (U.S.A.) stream (KRAFT 1964), 770 mayflies/m^2/yr for a German stream (ILLIES 1971), 392 — 2,635 mayflies/m^2/yr for various locations in a Scottish lake (MORGAN & WADDELL 1961), and 600 — 7,300 mayflies/m^2/yr from various Ontario (Canada) streams (IDE 1940).

Discussion

In only a few studies has the seasonal phenology of all mayfly species in a habitat been followed fo the entire emergence season. In Tab. 4 we have summarized the available North American studies. As one might expect, the emergence period of mayflies generally varies with latitude; however, variability will occur, partly because the immediate environment may differ from the general environment. Also some of the deviations in the relationship between emergence periods and latitude may be due to the different methods employed in the various studies. Nevertheless, there is a trend for both the length of the emergence season and the average length of the emergence period of individual species in a community to increase as one moves from the subarctic and cold temperate climates to the marine mesothermal and warm temperate climates. In warmer climates, the maximum emergence of total number of species as well as total numbers of individuals also becomes progressively earlier. In most regions of temperate North America the emergence period extends from April through the early part of October. Possibly the extent of the emergence period is in part limited by the length of time that the water temperature is above 7 °C, since this seems to be the lowest temperature at which mayflies have been found to emerge.

Summary

The emergence of mayflies from a small, slow-moving stream was followed for the entire emergence season (15 May to 1 Oct. 1973) by using floating box traps. *Baetis tricaudatus* DODDS, *Siplonurus alternatus* (SAY), *Siphloplecton basale* (WALKER) and *Paraleptophlebia debilis* (WALKER) comprised 66 % of the total emergence of 348 mayflies/m^2/year. During July, when 40 % of total emergence took place, 10 of the 14 species were emerging and daily emergence rates reached a maximum of 8.7 may-

Tab. 4. Emergence patterns of mayflies from various regions of North America.

	Number of species	Total length of emergence season (weeks)[8]	Length of species emergence period (weeks)			Time of maximum emergence	
			Mean[9]	Range		Number of species	Number of individuals
Alberta[1]	14	21	6	1	17	July IV[10]	July III
Michigan[2]	28	17	4	1	15	July IV	—
Michigan[3]	22	23	7	2	18	July IV	—
Oregon[4]	22	48	18	5	37	June II	June II
Arkansas[5]	34	40	5	1	15	May III	May II
South Carolina[6]	45	31+	10	1	31	May IV	—
Florida[7]	18	52	32	8	52	April IV	—

[1] Present study; [2] Leonard & Leonard (1962); [3] Lyman (1955); [4] Kraft (1964); [5] Peters & Warren (1966); [6] Carlson (1971); [7] Pescador & Peters (1974).
[8] The time interval between the emergence of the first and last mayfly, irregardless of species.
[9] Obtained by totalling the length of the emergence periods of all species, and dividing by the total number of species.
[10] Roman numeral denotes the week of the month.

flies/m². Although some emergence took place during almost all daylight hours, 91 % occurred between 15.00 and 22.00 hours MST. The emergence features of the brown-water stream mayflies are compared to the emergence features of mayflies from other regions of North America.

Acknowledgments

We appreciate the assistance of Miss Dyane Kalista. Financial assistance by the Boreal Institute for Northern Studies and the National Research Council of Canada is gratefully acknowledged. We also thank Mr. P. Carlson for providing us with some of his unpublished data.

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Correction added in proof:

Siphloplecton interlineatum should read *Stenonema canadense* throughout the paper.